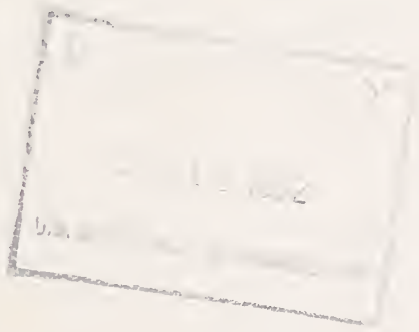
MISCELLANEOUS REPORT, NO. 13

BALSAM FIR IN MINNESOTA: A SUMMARY OF PRESENT KNOWLEDGE

By Eugene I. Roe



UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Lake States Forest Experiment Station

September 1950

September 1950

Miscellaneous Report No. 13

BALSAM FIR IN MINNESOTA - A SUMMARY OF PRESENT KNOWLEDGE

By Eugene I. Roe 1/
Lake States Forest Experiment Station 2/

INTRODUCTION

Balsam fir (Abies balsamea), considered an inferior tree a few years back, is becoming of greater and greater importance in the forest economy of northern Minnesota. There are two reasons for this changing situation. One is the constantly expanding use of this species by the paper industry as a substitute for the increasingly scarce spruce. The other is the large area of balsam fir forest which is gradually developing. The Forest Survey showed 1,083,000 acres of spruce-fir forest (predominantly balsam fir) in Minnesota in 1934 and recorded a definite understory of balsam fir and associated conifers (averaging more than 700 trees per acre) on nearly 1,000,000 acres of aspen type. A similar understory existed in some of the hardwood types -- both upland and lowland.

With the cutting and deterioration of the overstory, the balsam fir has assumed a more dominant position. By 1945 it was estimated that there were 1,210,000 acres of the spruce-fir type in Minnesota. Today, no doubt, there is a still larger area, although some is still rather poorly stocked. Barring catastrophies such as fires and epidemics, or undue interference from man, balsam fir may become a prominent if not dominant species on as much as 2 million acres in Minnesota.

Since the demand for this species seems likely to increase considerably as the supply of spruce diminishes, these balsam stands are bound to undergo a great deal of exploitation. To prevent a repetition of past mistakes will require intelligent management. Unfortunately, little is known as to the best silviculture for balsam fir in this region, although to all appearances it should be an easy species to manage. At present balsam fir generally is cut to a diameter limit which virtually amounts to commercial clear cutting. Although it usually comes back after such cuttings and will eventually produce a second crop, much greater returns might be realized from more conservative methods. Cutting studies are needed to determine this point.

1/ Forester, Headwaters Forest Research Center, Grand Rapids, Minnesota.
2/ Maintained by the U. S. Department of Agriculture, Forest Service, in cooperation with the University of Minnesota at University Farm, St. Paul, Minnesota

Before any studies of this kind are begun, however, it would seem worth while to take stock of what is known about balsam fir in Minnesota, its growth habits, conditions affecting regeneration, cutting practices, etc. To this should be added any information from other areas that might have application in this territory. Such a summary should not only be useful to forest managers and as background for cutting studies, but it will also indicate additional research needed. This report presents such a summary of knowledge.

HOW BALSAM FIR OCCURS

Balsam fir occurs in Minnesota in two general ways: (1) In stands where balsam fir alone or in mixture with white spruce is dominant (commonly called spruce-fir type3/), and (2) in stands where balsam is subordinate to the other species as an understory or secondary species in other forest types.

Stands Where Balsam Fir Predominates

Spruce-fir is the climax forest type in the northern part of Minnesota as well as in parts of northern Michigan and Wisconsin. Stands of old growth are composed of varying mixtures of balsam fir, paper birch, and white spruce, with some black spruce, aspen, white cedar, and an occasional black ash, red maple, and balsam poplar. In some areas, particularly along the North Shore of Lake Superior, yellow birch occurs with paper birch, or may even replace it. Where the succession is less advanced, there is considerable white pine and an occasional red pine. Toward the south and along the North Shore of Lake Superior, sugar maple, elm, and basswood, species characteristic of the hardwood climax forest, may occur in the mixture. A good deal of fir, however, is found in pure, somewhat scattered stands of younger age. These may have originated after fire or windstorm, after logging, or following epidemics of the spruce budworm. Such areas are usually not very extensive in area, as it is hard to find more than 10 acres in one condition class. This is in striking contrast to species like black spruce, jack pine, or aspen, which often form extensive stands of uniform character.

Stands Where Balsam Fir is Secondary

An appreciable amount of balsam fir occurs as a secondary species in other forest types either as a part of the overstory, such as in jack pine, black spruce, and white cedar stands; or as an understory of varying size and density under aspen, paper birch, jack pine, and occasionally red pine. In the natural course of events, the latter type of stands will eventually go over to balsam as the overstory dies. Considerable balsam fir in Minnesota has become dominant through such succession; this is particularly true in those areas which have escaped burning for many years.

3/ This is the white spruce-balsam fir-paper birch type of the Society of American Foresters (Forest Cover Types of the Eastern U. S., 3rd Edition, revised 1940). Actually, there is almost always more balsam than spruce in the type.

WHERE BALSAM FIR OCCURS

Practically all the balsam fir in Minnesota is found north of a line extending roughly from Hinckley to Little Falls, Park Rapids, and Detroit Lakes. To the south and west of this line it is scattered and of little commercial significance. The more important areas producing balsam fir occur in Cook, Lake, St. Louis, Itasca, Koochiching, and Beltrami counties. Considerable quantities are also found in Aitkin, Carlton, Cass, and Lake of the Woods counties.

For best development, balsam fir appears to need an abundance of moisture. As a result, the best balsam fir usually is found on the heavier upland soils or on the lowlands bordering swamps (semi-swamp). In the northern part of the State, it is occasionally found on light soils, such as gravelly sands, that farther south would not support balsam. On such sites, however, its development is rather poor. True swamps or bogs are apparently too wet for balsam fir as relatively little occurs on peat of any depth; when the tree is found on such sites, it is usually intermingled with black spruce and is very poor in form, quality, and growth.

So far as is known, balsam fir reaches its best development in Minnesota on the bed of glacial Lake Agassiz in Beltrami, Koochiching, and northern Itasca counties. The soils of this region generally are heavy clay loams and silt loams -- and have an abundance of lime at shallow depth. Another area of perhaps equally good sites occurs in the so-called "birch belt," a strip of about 10 to 25 miles wide extending along the North Shore of Lake Superior from Duluth to beyond Grand Marais. This is a region of generally heavy soils with somewhat slow drainage. Part of this area may consist of soils laid down during the glacial Lake Duluth stage of Lake Superior and hence also contain considerable lime. The largest balsam firs so far recorded in Minnesota have been cut in the "birch belt." In the absence of specific information, it would seem logical to assume that the dry sandy moraines and the wet swamps will be poor balsam fir sites and the fertile upland and swamp margin soils will be good balsam sites. It has been observed that on land where aspen and white cedar make good growth, balsam fir also makes good growth.

AREA, VOLUME, AND CONSUMPTION OF BALSAM IN MINNESOTA

Area of Spruce-Fir Type

The original area of the spruce-fir forest type in Minnesota was estimated by the Forest Survey to have been about 6,300,000 acres (12)[4]; it comprised most of the upland forest north of a line extending from Duluth to Crookston. Logging for white pine, spruce, and cedar sawlogs, and to some extent for birch ties, followed by fire and land clearing, has greatly reduced this area so that in 1945 only about 4,300,000 acres of spruce-fir land were estimated to be forested (3). Of this area, about 1,200,000 acres are still occupied by the original type, including 300,000 acres less than 40 percent stocked, while about 3,000,000 acres are in aspen or paper birch.

---

[4] Underlined numbers in parentheses refer to literature cited.

Well over half of the satisfactorily stocked forest land, or 500,000 acres, is in reproduction stands; the remaining 420,000 acres are in cordwood and saw timber. Most balsam fir saw timber is reported to be overmature, whereas the cordwood stands are at a stage calling more for thinnings than harvest cuttings.

No reliable figures are available as to the proportion of balsam fir land in different types of ownership. Although much of it is in federal (National Forests and Indian Reservations), as well as state and county ownership, there is still a considerable amount privately owned. The pulp and paper companies own an appreciable acreage of balsam fir land, but probably the larger share of the private land is in small farm holdings, mostly in St. Louis, Itasca, Beltrami, Lake of the Woods, Koochiching, and Lake counties.

Volume of Balsam Fir

The estimated stand of balsam fir in Minnesota in 1945 was 5,300,000 cords, most of which occurred within the balsam fir-spruce type. Of the volume, 39 percent was in St. Louis, Carlton, and the northeastern counties of the State; 37 percent in Itasca, Beltrami, Cass, and Aitkin counties; and 21 percent in Koochiching and Lake of the Woods counties. The remainder was in scattered stands in Roseau, Marshall, and Becker counties (3).

Fifteen percent of the volume was in trees of sawlog size; the remainder was in smaller trees (3). Average mature stands contain 8 to 12 cords per acre. Many stands are not fully stocked.

Present Use of Balsam Fir

Although some balsam fir is cut into lumber,5/ particularly the large-sized trees in the "birch belt," the greatest use is for pulpwood. A considerable number of small trees, and to some extent the tops of merchantable trees are used for Christmas trees. A very small but steady market exists for the resin contained in the bark blisters.

The use of balsam fir as pulpwood is rapidly increasing in Minnesota. Such use accounted for an average of only 77,000 cords annually during the decade 1935 to 1944. Since that time it has almost doubled, the State producing 150,000 cords in 1948, the last year reported. About half of the pulpwood produced is used by Minnesota mills, the rest goes to Wisconsin or outside the region (9).

If production continues at the 1948 rate, we will presumably be cutting balsam fir faster than it is growing for the annual allowable drain of balsam fir cordwood (exclusive of saw timber) for the next 20 years was estimated at 115,000 cords in 1946 (3). This figure, however, makes no allowance for increase in acreage of the type, and there seems little doubt but that the area of balsam fir is increasing rapidly.

5/ According to Horn (10) about 5 million board feet of balsam fir lumber was produced in Minnesota in 1948.

SILVICAL CHARACTERISTICS OF BALSAM FIR

Growth Habits

Balsam fir is a small to medium-sized tree of rapid growth once it is beyond the seedling stage. In the Lake States, it occasionally reaches diameters of 22 inches and heights of 80 feet ("birch belt"), but trees in average stands are much smaller and shorter than this; more usual are trees of 8 to 10 inches d.b.h. and 45 to 55 feet in height.

Balsam fir in the northeastern states apparently attains a larger size than in this region, for according to Zon (28) trees in Maine reach a height of 95 to 100 feet and a diameter of 25 to 30 inches. Mature trees, however, are usually 12 to 16 inches in diameter and 70 to 80 feet high. He reported that the growth rate of balsam fir in Minnesota was poorer than that in New York or New England.

Growth begins early, sometimes before the last frost which kills the tender shoots. The flowers are mature about a week before the leaves are produced -- about the last week in May at Ely -- from buds which are readily visible the preceding fall. They may be killed by late frosts and the cone crop thus wiped out. Fertilized cones, borne in the extreme top of the trees, develop rapidly and usually mature the last week in August to early September. Height growth is very slow during the first 5 or 6 years of life, after which, unless the trees are suppressed, it becomes quite rapid until about 80 years, when it practically ceases (28). Diameter growth apparently continues up to death (28). Trees with plenty of light or a released understory of balsam fir less than breast height but fairly old can reach merchantable size in 30 to 35 years, but it is doubtful if commercial stands could be produced from seedlings in this period.

Balsam fir occurs both in even-aged and many-aged stands. The former probably have originated mostly after fire and occasionally after blow-down, and budworm epidemics. Many-aged stands develop in the absence of fire or other catastrophe.

Many stands of balsam fir are severely suppressed over greatly varying periods of years before release. A study of such stands made by Morris (18) indicated that the age of the stand since initial release provided a better guide to the growth rate, sexual maturity, and onset of butt rot in the stands than the total age. Since most of the suppression occurs before the trees reach breast height, there is a present tendency to determine the age at that point instead of total age for balsam fir.

Balsam fir is very tolerant (possibly the most tolerant of Lake States conifers). It produces internodal buds and bears many branches which remain alive for years and when dead do not prune readily. Due to their tendency to produce new shoots from adventitious buds, balsam firs can produce new tops when the old one is killed or broken off. This habit is the basis for the practice of leaving live whorls of branches on the stubs remaining from Christmas tree cuttings, thus enabling them to produce new trees.

Longevity, Mortality, and Cull

Balsam fir is a relatively short-lived tree. Reports from New York (28), Ontario (2), Quebec[6], and Minnesota (11), refer to 150-year-old trees and from New Hampshire, 176 years (25). Trees of such advanced age appear to be rare in Minnesota, few attaining an age of more than 100 years.

Probably the main reason why balsam fir does not live longer is its susceptibility to insect attack and to decay. The spruce budworm (Cacoecia funiferana) periodically becomes epidemic and with its associated bark beetles and borers kills large volumes of timber. Carpenter ants, by their weakening effect at the butt are a constant although indirect cause of loss from wind breakage. Contrary to general opinion, these ants are found about as often in otherwise sound balsam fir as in those which are decayed (25). Other insect pests attacking this species but rarely causing serious damage are the false hemlock looper, the balsam fir sawfly, and the balsam woolly aphid.

Less spectacular in their effects than budworm but perhaps just as important a source of mortality are the white stringy butt rot caused by Poria subacida and the brown butt rot caused by Polyporus balsameus. These, like carpenter ants and often in conjunction with the latter, so weaken the trees that they break off near the base or are uprooted during strong winds. Very old trees are also likely to be seriously infected with a red heart rot or top rot caused by Stereum sanguinolentum. This type of rot which is usually confined to the upper part of the bole seldom causes mortality. It may, however, account for the loss of tops during heavy seed crops. Other balsam fir diseases which may occasionally be important in some localities are the brown butt rot caused by Polyporus schweinitzii, peaky wood rot caused by Trametes pini, rust witches' broom, and various needle rusts.

Due to its shallow root system (little if any deeper than that of spruce) balsam fir is less windfirm than most northern conifers. It is not always possible to determine, however, how much of such windthrow may be due to decayed roots.

Balsam fir, because of its thin bark and low crown, is easily killed by fire. Nor can it withstand very long periods of flooding.

As a result of the various types of mortality to which it is subject, stands of balsam fir tend to open up with age unless regenerated. Often such regeneration occurs but in other cases brush may come in.

Besides the sizable amount of volume lost through windthrow of decay-weakened trees, wood-rots in balsam fir are responsible for considerable loss through the culling of the butt or upper logs at the time of cutting. The great importance of such cull in the northeast is stressed by Spaulding and Hansbrough (25) who made detailed stem studies of some 1,100 balsam firs ranging from 40 years up. Half of these trees showed decay severe enough to cause some cull at 72 years and all at 165 years. Top rot was the greatest cause of cull, but its importance was exaggerated by the fact that trees with butt rot are lost through windfall. Butt rot appears in some trees at 40 years and

---

6/ Verbal report from H. A. Bess, formerly with U. S. Bureau of Entomology and Plant Quarantine, Milwaukee, Wisconsin, 1947.

gradually becomes so serious that the authors recommend a rotation age of 70 years to keep cull losses at a minimum. Cull appeared to be more serious on poor sites than on good ones, but the volume so lost was greater in fast growing trees than in those of slow growth.

The importance of the butt rots in the Lake States has been pointed out by Kaufert (11), who found that 80 percent of trees 90 to 100 years old and practically all those 130 years old show such decay. He concludes that cull from butt rot increases so rapidly after 70 years of age that balsam fir should not be held after it is 80 years old. His opinion that balsam fir on ridge tops are more susceptible to butt rot than swamp trees is confirmed by the subsequent work of Heimburger and McCallum (7), who found the two common butt rots to be more serious in the Aster site type (mixedwood slopes on ridges) than in the Cornus site type (softwood flats or semi-swamps). The earlier studies of Moore and Rogers (17), however, indicated that mortality from butt rot in Maine became serious at an appreciably earlier age on the flats than on the slopes.

Conditions Affecting Regeneration

Seed Supply

Balsam fir is a rather prolific seed producer. Production begins at about 20 years[7] and apparently continues until death. Good crops appear to be borne in northern Minnesota every two or three years, with some seed borne almost every intervening year. Bonner (2) reports dominant and codominant trees to be the heaviest producers. Nothing is known as to the amount of seed produced by individual trees or by balsam fir stands during a good year. However, a series of 20 traps set out near Ely, Minnesota, with reference to white spruce seed trees, but with considerable small, 50-year-old balsam firs in the stand, showed a production of 940,000 viable balsam fir seeds per acre in a heavy seed year (24).

A bushel of balsam fir cones was found by Richardson (19) to weigh 35 pounds and to yield 2.3 to 2.6 pounds of cleaned seed. The seed if properly cleaned shows good germination and averages 60,000 cleaned seeds per pound;[8] it is thus the largest Minnesota conifer seed except for white pine and red pine. Although balsam fir seed will not keep as well as pine seed, it should retain its viability for many years if properly handled. Seed stored for seven years in sealed containers at about 40° F. showed little loss in germination. In absence of such conditions storage in tightly closed containers in a cool dark cellar should prove a fair substitute (22).

7/ One tree was found to have produced viable seed at about 15 years (23).

8/ Cleaned balsam fir seed includes the wing bases. These are impossible to remove without injuring the soft seed, since they enclose the seed on three sides. These bases absorb considerable moisture and because of this may help in germination.

Seed fall begins about a week after ripening (usually late August to early September) and slowly continues throughout the fall to the early spring months (2, 21). The seed is dispersed mostly by wind, although squirrels also play a part through their caching activities. Average distance dispersed is not known; the maximum known distance is 7 to 8 chains. According to Bonner (2) many seeds stick to the resinous cone scales and fall near the parent tree while others appear to be blown long distances.

It is probable that birds and rodents eat considerable seed. Mice are known to cache the seeds and squirrels hide and later destroy at least some of the cones.

Seedbed Requirements

Of the three more common types of seedbed, mineral soil is apparently the best with rotten logs a close second. The latter commonly occupy only a small proportion of the ground and hence are relatively unimportant. Duff is the poorest seedbed. (13, 20) However, some balsam fir seedlings manage to penetrate the duff and come into contact with the more readily available moisture of the mineral soil. Hence, although mineral soil is a much better seedbed many balsam fir seedlings do become established on duff, particularly in seasons with abundant moisture. This ability to come in on duff is probably one of the major factors responsible for the increasing dominance of balsam fir in the northern forest.

Time of Germination

At Ely, Minnesota balsam fir seed has been observed to begin germination in the forest in late May and to be three-quarters complete by the end of June; the remainder germinates mostly in July. Germination on duff occurs largely in July and August and appears to be slower than that on mineral soil. Balsam fir seed is dormant, and will not germinate well unless given a long period of stratification at low temperatures (22). 9/ In nature this requirement is taken care of as the seed lies on the ground over winter. Seeds which fall late in winter probably lie on the ground over one summer.

Growth Rate of Seedlings

Initial growth of balsam fir seedlings is slow. However, the root grows down into the soil faster than that of white spruce seedlings (probably because of the larger seed and consequently greater amount of stored food) and hence balsam fir seedlings can survive dry weather the first summer better than can white spruce. Growth under the more ideal conditions of a forest nursery is also slow. At least 2-2 stock is required for field planting, and 3-2 might even be better. Early growth of natural seedlings in the open is somewhat slower, the trees attaining a height of from 1/2 to 1 foot in 7 years. From then on they grow at an increasingly rapid rate. If suppressed, however, they may persist for years making a minimum amount of height growth. 10/

9/ Judging from studies made by Heit and Eliason (8), balsam fir seed from the northeast may have less pronounced dormancy and hence require a shorter period of stratification.

10/ The writer once found a suppressed balsam that was 5 feet high and 36 years old; it was badly rotted at the base.

Brush and Overhead Cover

Since balsam fir is a very tolerant species, many 1- and 2-year-old seedlings are often found under dense brush or dense overhead cover. 11/ These seldom survive, for there is apparently a minimum light intensity below which balsam seedlings cannot exist. What this level is, is not known. Under lighter brush or under a more open crown canopy, the seedlings will persist for years making very slow growth. If given more light they will recover from suppression and grow as if they had had full light from the start. 12/ Under species with light crowns, such as aspen and birch, balsam fir, although not attaining its full growth potential, nevertheless manages to maintain a fair to good rate of growth. Hence it is only a matter of time until balsam fir becomes the dominant tree in such stands.

Long continued suppression, however, aside from loss of growth has other undesirable features. It has been found in the northeast that trees up to 70 years of age are somewhat more susceptible to decay when suppressed than when growing rapidly. (25) Further, the fungus causing top rot infects many trees which have been suppressed long enough to become flat-topped (25, 28).

Although balsam fir makes rapid growth when released, sudden exposure probably is harmful. This seems to be true in the case of older, less vigorous trees which are left as unmerchantable on logging operations, and also of scattered trees up to 25 years old, which are given complete release. The former trees are subject to sunscald and blow-down while the younger trees, according to Schantz-Hansen13/ are likely to blow down or be broken by snow. Damage of this kind is especially noticeable on the ledge-rock formation of northeastern Minnesota. Dense understories of young balsam fir, when given full release, apparently come through in better shape than do scattered trees.

Enemies of Balsam Fir Seedlings

Balsam fir seedlings have many enemies. Probably the earliest are the damping-off fungi which attack the young seedlings soon after they emerge. Damping-off accounted for 43 percent of the determinable first-year mortality in balsam fir seedlings in a study made in 1940 14/, and 25 percent in another made in 1948 15/. Some unknown insects destroy the cotyledons and some years apparently kill many seedlings (56 percent,14/ 5 percent15/). Dry seasons also cause considerable loss the first year; that of 1948 was responsible for 68 percent of the mortality on some natural reproduction quadrats near Ely and with other agents reduced the stand from 322,000 to 60,000 seedlings per acre. Balsam fir seedlings, however, are more drought resistant than those of white spruce (1).

11/ A reproduction study in a 70-year-old white spruce stand of good density showed 3,900 balsam seedlings per acre; of these 90 percent were under 6 inches in height and 9 percent were in the 1-foot class (24).

12/ Balsam fir stumps have been observed which showed that the tree had made fast growth after being badly suppressed for 50 years. In Newfoundland balsam fir left after moderate cutting in stands suppressed for 70 years show excellent response in growth (16).

13/ Information obtained verbally, 1950.

14/ LeBarron, R. K.- 1941. Unpublished data on balsam fir direct seeding in files of Lake States Forest Experiment Station.

15/ Roe, E. I.- 1949. Unpublished data from quadrat studies of natural reproduction of balsam fir and white spruce. In files of Lake States Forest Experiment Station.

Some seedlings are killed by frost heaving and others are smothered under the leaf litter during the first winter. Phacidium blight is reported to kill small seedlings under snow and also the lower branches of larger trees in Ontario (2). As the seedlings get larger, they may be browsed by deer or moose and nipped by hares. Such damage, however, seems of importance only in the brushy lands on the North Shore. Hares occasionally girdle the bark of seedlings 4 to 5 feet high; in times of high population such damage is probably serious. Mice are reported to cut off some seedlings at the ground line. Now and then porcupines will girdle the tops of 2- and 3-inch understory trees. The new leaders and laterals are often killed back by late spring frosts.

Reproduction by Layering

Balsam fir like black spruce, can reproduce by layering of the lower branches. While this is generally of little importance (Bonner (2) estimates that layers form one percent of the balsam reproduction in the Clay Belt of northern Ontario) locally, it may be abundant. Near Ely, in northeastern Minnesota, layering is fairly common on the north slopes of a gravel ridge; as a whole it appears to be rare. Occasional dense clumps of balsam fir saplings are doubtless of layer origin.

GROWTH AND YIELD OF BALSAM FIR

As a result of the cooperative effort of state, industrial, and federal foresters, over 500 balsam fir yield plots were measured in Michigan, Wisconsin, and Minnesota during 1948. These data have been analyzed and a report issued by the Lake States Forest Experiment Station (5). The tables of growth and yield of balsam fir in the Lake States comprise the most up-to-date information on this subject, and hence fill what has been an important gap in our knowledge of this species. They can be used for both pure and mixed upland stands and require the estimation of such stand characteristics as proportion of balsam fir, stand age, site quality, and competition index. The last factor measures the combined effect on growth of the degree of density and the amount of competition offered by larger trees. Site quality is determined from the average volume per tree as it relates to age and degree of competition.

BALSAM FIR CUTTING PRACTICES

Most of the larger trees in balsam fir stands now being cut are overmature. The common cutting practice is to remove all trees larger than 6 inches d.b.h. containing more than one 100-inch pulp stick. In some more accessible areas, the 2-stick balsam firs are reserved from cutting. Generally, however, not much consideration is given to the age of the stand, the uneven-aged stands being cut like the even-aged ones.

White spruce when associated with balsam fir is either cut to a diameter limit varying from 6 to 12 inches, or on state and national forest sales and some private operations may be marked on a thrift basis. Other associates are usually cut to a diameter limit.

Utilization in balsam fir cuttings is generally to a 4-inch top as in the case of other conifers; on some operations it is to a 3- or a 3½-inch top.

Disadvantages of Current Practices

Balsam fir, because of its aggressive regenerative ability probably can stand more abuse than any other Lake States conifer. Six-inch diameter-limit cuttings in this type, although virtually commercial clear cutting, do not usually leave the land in a denuded condition due to the presence of varying amounts of large advance reproduction and trees just under merchantability. 16/ As a result such cutover lands generally make a rather rapid come back, and a second cut is assured. However, certain characteristics of the cutting system used, together with other undesirable practices, tend to delay the second cut for many years and also to reduce its yield.

When balsam fir is cut to a 6-inch limit, a great deal of slash results, especially where utilization is not close. This not only smothers many established seedlings but for many years it also prevents seedling establishment on a considerable proportion of the cut-over area. 17/ Consequently, such a cutting will later assume a somewhat patchy pattern of stocked areas mixed with others that are not, or in a younger age class interspersed with areas of older timber.

Such cutting also results in considerable exposure of the site and, particularly on the shallow soils of the ledge-rock area in northeastern Minnesota, is often followed by much windthrow in the 3- and 4-inch trees, those which are the nucleus of the second cut. Intermediate and suppressed trees may be severely affected by sunscald when exposed by logging, and such injury serves as an infection center for decay. Invasion by brush is also encouraged on some areas by the great amount of exposure afforded by such cutting.

Another drawback of cutting to a 6-inch diameter limit in uneven-aged stands is that it greatly reduces growth through eliminating the fastest growing trees in the stand, that is the 6- and 8-inch trees. This reduction will be apparent for at least two decades.

To the rather considerable loss of potential second-crop trees caused by slash damage to advance reproduction, reduction in valuable growing stock, and the sudden exposure of small nonmerchantable trees, must also be added the destruction of saplings and small poles during logging and skidding. Although some of the loss is unavoidable, much of it could be prevented by

---

16/ An exception to this is the brushy lands of the "birch belt" where there are practically no small trees in the stands and very little advance reproduction. Logging here presents difficult problems as timber volumes are relatively light and reproduction is hard to establish under the heavy brush. The best balsam fir reproduction here appears to have come in on the lower lying swamp-margin sites where the brush is much lighter than on typical upland.

17/ In northeastern Minnesota, slash piles created 5 years ago in typical balsam cuttings are still not available for seedling establishment. Bonner (2) feels that in northern Ontario such areas cannot be counted on for 10 to 15 years.

care in logging. The importance of this problem is demonstrated by Bonner (2), who reports that 40 to 70 percent of the advance growth is destroyed during logging operations in the Clay Belt of northern Ontario. Similarly, a study of some National Forest and private cuttings in northeastern Minnesota in 1945 showed that from 5 to 45 percent of the trees from 1 to 4 inches d.b.h. were either cut or broken off during logging operations; no information was obtained for seedlings below these sizes.

The end result of these various factors affecting mortality and reproduction is a greatly lengthened cutting cycle. On some areas the possibility of a second commercial cut is probably delayed for about 40 to 50 years, and during this period many of the 3-inch to 6-inch trees which survived the hazards of logging will reach maturity and die. The resulting loss in yield is emphasized by Day (4) and by Westveld (27). The latter finds that average spruce-fir stands in Maine cut to what approximates a 6-inch diameter limit will actually produce about 12 cords per acre during a 60-year cutting cycle. However, only half of this is ever harvested, the rest being lost through mortality mostly between 30 and 60 years. Westveld contends that by changing to a 30-year cutting cycle, the owner could obtain an additional 3.6 cords per acre; and by reducing the cutting cycle to 20 years could realize an increase of 4.2 cords per acre. Although data are not available, it seems probable that much of the same kind of losses are taking place in Minnesota under existing practices.

Feasibility of Selection Cutting in Balsam Fir Stands

Many of the disadvantages inherent in the present diameter-limit cutting of balsam probably could be overcome by handling this species under the selection system (a combination of tree and group selection, depending on the stands). Theoretically balsam fir seems ideally suited for such cutting -- it is very tolerant of shade and can reproduce under low light intensities, and on seedbeds that would be unfavorable to most other species. Seedlings once established will make slow but dependable growth if given more light and very rapid growth if the stand is opened up further. Furthermore, much balsam fir already exists in uneven-aged stands thus testifying to the fact that this type of silviculture is natural.

Under the selection system losses from mortality should be low. Slash also would be little problem for there would be much less to begin with and under the shade furnished by residual stand, this would decay and disappear much more rapidly. 18/ There would be no serious fire hazard such as that afforded by balsam fir slash under present practices. Brush invasion would be kept at a minimum as would also losses from windthrow and sunscald. More care, however, would have to be exercised by the logger but this is a must under any cutting system.

18/ Balsam fir slash on the ground under the brush canopy of the "birch belt" completely disappears in 3 to 5 years.

Such a cutting system to be most effective should be operated on fairly short cutting cycles. The yield advantage of a 20-year cutting cycle as demonstrated by Westveld (27), has already been discussed. It is believed such a period would prove practicable in the more remote areas, while in more accessible country the period might be reduced to 10 years and possibly to 5 years in the farm woodlots of northern Minnesota. Although no proof is yet available it seems reasonable to believe that the greatest yields from balsam fir will be obtained from light cuts repeated at short intervals and begun at an early age.

The selection system is applicable to all balsam fir stands excepting even-aged stands which are nearing the pathological rotation age of 70 to 80 years (11, 14, 25). The latter type can, according to Day (4), be handled in two cuts the first of which removes about one-fourth of the merchantable volume in trees of the poorest vigor. Once reproduction is well established, the remaining timber can be removed (4). Thrifty even-aged stands of intermediate age presumably can be handled on the selection basis and gradually converted into an uneven-aged condition.

Any application of the selection system implies marking which, of course, involves a certain amount of expense. In stands where the diameter is definitely in proportion to age, designation to a diameter limit of 8 or 9 inches will probably prove a fair substitute for marking. For best results in any stand, however, marking will be necessary.

The statement has been made that any handling of balsam fir will be determined by the budworm. This is, of course, true. Balsam fir overtopped by aspen, birch, or by other conifers apparently is not subject to budworm attack, the most susceptible trees being the large overmature individuals which form or project above the upper crown canopy (6). In New England budworm risk is rather closely associated with rate of growth and this in turn with a combination of vigor, crown class and crown ratio (15). Therefore it would seem that if balsam fir stands are kept in a thrifty, rapid-growing condition and areas of overmature (also slow-growing) trees kept at a minimum, the possibilities of serious losses from budworm should be rather small.

In all cutting of balsam fir the goal should be to encourage as much reproduction of white spruce as possible. Sound, thrifty trees should be retained as long as possible, not only because of their seed production but also because of the excellent growth rate maintained by this species even at an advanced age.

Utilization down to a 3-inch minimum top diameter should be encouraged. Although how much increased yield would thus be obtained is not known, it is likely very appreciable.

ADDITIONAL STUDIES NEEDED

The following studies seem to be indicated on the basis of present knowledge of balsam. These are arranged more or less in the order of their present priority.

1. Cutting Studies in Mature Balsam Fir

These should be directed at increasing both the yield of balsam fir over the rotation and the amount of the more valuable white spruce in the stand. Studies are needed in both even-aged and uneven-aged stands and should be located in different parts of the State. They should compare light, frequent cutting (10-year intervals) and heavier, less frequent cutting (20-year intervals), both made on a thrift basis, with the present 6-inch diameter limit cutting. The State Division of Forestry has a cutting study at Orr, and the Lake States Forest Experiment Station has started one on the Chippewa National Forest. Special studies are also needed in the light very brushy stands of the "birch belt." These are discussed further under 5 below.

2. Logging Costs and Other Economic Studies

Hand in hand with cutting studies should go studies of the cost of producing balsam fir pulpwood under different methods of cutting compared with 6-inch diameter limit cutting. Included should be cost of marking, felling, bucking, skidding, etc.

3. Cutting Studies in Mixed Stands Such as Aspen or Birch and Balsam Fir.

The object here would be to determine total yield under practices varying all the way from complete removal of overtopping aspen and birch to complete removal of the balsam. The Lake States Forest Experiment Station has such a study under way on the Argonne Experimental Forest in Wisconsin.

4. Thinning Studies in Immature Balsam Fir

Thinning studies in immature balsam fir, with the object of speeding up growth and utilizing mortality. Thomson (26) reports a stand of 755 balsam firs per acre to have 2,100 more cubic feet of merchantable material per acre than one of the same age and on the same site with 2,500 trees per acre, so it would seem that thinning in balsam would have decided advantages. Thinning in very dense stands would probably have to be done gradually to prevent damage from sudden exposure or from snow. According to Day (4) thinnings in stands 30 years old can produce Christmas trees as well as a small amount of pulpwood. The Minnesota and Ontario Paper Company has a small thinning study in balsam fir, but so far as known this is the only one of its kind in the State. Additional studies should be started as soon as possible and should include the economic as well as the silvicultural aspects.

5. Restoring Brush Lands to Productivity

A large area of potential balsam fir land is occupied by brush or by light stands of balsam fir, white spruce, and birch, with a very dense understory of brush. Cuttings on this latter type of land, most of which appears to be confined to the "birch belt," present very difficult problems. The timber is overmature and will not stand up under partial cutting, hence clear cutting is the only recourse; cull is high, especially in birch, so yields are low and many defective "wolf" trees are left. There is no advance growth and, due to a combination of heavy duff with dense brush 15 to 20 feet high, natural seedlings cannot get started nor can planted trees survive. Until the brush problem is overcome there seems no hope of getting these rich sites back into full production.

Disking seems to offer possibilities of knocking down the brush as does also the use of herbicides. The Superior National Forest and the Lake States Forest Experiment Station already have some preliminary trials of these methods in combination with direct seeding and planting under way in the "birch belt." They should doubtless be tried on other balsam fir lands in the State where the brush problem, although bad, is not so critical.

6. Conversion of Inferior Stands to Balsam Fir

Also needed, although somewhat analogous to the preceding, is a study to determine if land now occupied with sapling stands of poor hardwoods or by medium stocked aspen can be converted to balsam fir and white spruce by disking or herbicides in combination with seeding and planting. There is much land of this type on the Chippewa National Forest and elsewhere in north-central Minnesota, which ecologically is transitional between balsam fir land and hardwood land. The hardwoods generally are of poor to fair quality, so balsam fir-spruce may be the more economic type here. In connection with this and the previous study, opportunity should be afforded to determine just how much help balsam fir needs in the way of release to come through brush successfully.

7. Logging Damage in Balsam Fir Stands

How much are potential yields reduced by needless use of immature trees as skids, cutting of small trees to make felling and bucking easier, smothering of small reproduction by slash, wide skid roads, etc.? Some information on these points should be gathered in connection with the cutting studies listed under 1.

8. Site Classification of Balsam Fir Stands

Site classification of balsam fir stands and how to identify the various balsam fir sites. Are the site qualities used by Gevorkiantz and Olsen (5) in their growth and yield tables correlated with any easily recognizable factors such as topography, soil, and vegetation?

9. Fundamental Studies of the Common Brush Species Found in Balsam Fir Stands

Of particular value would be studies of brush species in the "birch belt" where hazel and mountain maple reach 20 feet in height and the latter 2 to 3 inches d.b.h. A study of hazel brush is now being carried on at the University of Minnesota which will probably be of considerable aid. The other common species also need detailed study especially in this area.

10. Nursery Studies

Balsam fir planting stock is produced in negligible quantities at the present time, and there is very little knowledge on how to grow it. It is known that the seed should be fall sown, that the seedlings should be shaded the first two years in northern Minnesota, and transplanted at the end of the second year. Apparently 2-2 stock is satisfactory. There seems to be considerable difference between seed laboratory and nursery germination. Since planting of balsam fir appears to be the only way to restore forest cover on the extremely brushy sites, more experience with this species is needed. This calls for the actual production of balsam fir stock.

11. Planting Practices

Nothing seems to be known as to proper planting practices for this species. Presumably it can be hand planted with a mattock. Possibly it can also be machine planted on areas not too brushy to interfere with the planting machine. Trials of both methods should be made on a sizable scale.

12. Ecological Study of the "Birch Belt"

This area of good sites occupying an estimated 300,000 to 400,000 acres in Lake and Cook counties needs a thorough study. Important questions that need to be answered are:

Why is the virgin forest regressing here so that brush is taking over to such an extent that the climax species are being excluded?

Why is the birch so short boled and defective, although it attains large diameters and the sites are apparently good for this species?

Is this sharply defined belt, which apparently also occurs in Ontario north of Lake Superior, associated with some definite type of climatic and soil conditions? It has been said that the poor condition of the birch is the result of natural decay following excessive top breakage caused by a severe glaze storm back about 1910. If so, such opening up of the stands might have encouraged the invasion of brush. Another possible cause of the present dominance of brush is the death of much of the mature balsam fir in the early 20's due to budworm attack.

13. Relation of Cull to Site Quality

Preliminary studies in Quebec and in New England indicate that there is a relationship between site quality and the amount of cull in balsam fir (7, 17, 25). The results, however, are somewhat conflicting. When balsam fir sites are finally defined in this section of its range, it would seem worthwhile to make a detailed study of this relationship. If cull is definitely related to site quality, net yield could be predicted much more closely than at the present time.

14. Effect of Suppression on Cull

More work needs to be done to find out how much long periods of suppression affects cull.

LITERATURE CITED

(1) Bedell, G. H. D.
1948 White spruce reproduction in Manitoba. Canada Dept. Mines and Resources, Dominion Forest Service Silvic. Research Note 87, 16 pp. (proc.).

(2) Bonner, E.
1941 Balsam fir in the clay belt of northern Ontario. Master's Thesis, University of Toronto, 102 pp. (typed).

(3) Cunningham, R. N.
1946 Revised forest statistics for the Lake States, 1945. U. S. Forest Service, Lake States Forest Experiment Station, Station Paper No. 1, 27 pp. (proc.).

(4) Day, M. W.
1945 Spruce-fir silviculture. Mich. Agr. Exp. Sta. Quart. Bul. 28(1): 59-65.

(5) Gevorkiantz, S. R. and Olsen, L. P.
1950 Growth and yield of upland balsam fir in the Lake States. U. S. Forest Service, Lake States Forest Experiment Station, Station Paper No. 22, 24 pp. (proc.).

(6) Graham, S. A. and Orr, L. W.
1940 The spruce budworm in Minnesota. Minn. Agr. Expt. Sta. Tech. Bul. 142, 27 pp., illus.

(7) Heimburger, C. and McCallum, A. W.
1940 Balsam fir butt-rot in relation to some site factors. Pulp and Paper Mag., Canada, 41: 301-303.

(8) Heit, C. E. and Eliason, E. J.
1940 Coniferous seed testing and factors affecting germination and seed quality. N. Y. State Agr. Exp. Sta. Tech. Bul. 255, 45 pp., illus.

(9) Horn, A. G.
1949 New record cut of pulpwood in the Lake States, 1948. U. S. Forest Service, Lake States Forest Experiment Station, Tech. Note No. 320, 2 pp. (proc.).

(10) Horn, A. G.
1950 Commodity drain from the forests of the Lake States, 1948. U. S. Forest Service, Lake States Forest Experiment Station, Station Paper No. 20, 37 pp. (proc.).

(11) Kaufert, F. H.
1935 Heart rot of balsam fir in the Lake States, with special reference to forest management. Minn. Agr. Exp. Sta. Tech. Bul. 110, 27 pp., illus.

(12) Lake States Forest Experiment Station
1933 The forests of Minnesota - Areas and Types. U. S. Forest Service, Lake States Forest Experiment Station, Econ. Note No. 1, 25 pp. (proc.).

(13) LeBarron, R. K.
1946 Mineral soil is favorable seedbed for spruce and fir. U. S. Forest Service, Lake States Forest Experiment Station, Tech. Note No. 237, 1 p. (proc.).

(14) McCallum, A. W.
1946 Control of forest disease through management. Canadian Pulp and Paper Assoc. Woodl. Sec. Index 827 (F-2), 3 pp.

(15) McClintock, T. F.
1948 Evaluation of tree risk in the spruce-fir region of the northeast. Iowa State Col. Jour. Sci. 22(4): 415-419.

(16) McCraw, W. E.
1948 Growth of balsam fir in Newfoundland. Pulp and Paper Mag. Canada 49 (3): 280, 284, 286.

(17) Moore, B. and Rogers, R. L.
1907 Notes on balsam fir. Forestry Quart. 5(1): 41-50.

(18) Morris, R. F.
1948 How old is a balsam tree? Forestry Chron. 24: 106-110.

(19) Richardson, A. H.
1935 Unpublished data on collection, extraction, and cleaning of tree seed. Ontario Dept. of Lands and Forests, Toronto (typed).

(20) Robbins, P. W.
1930 Need mineral soil for spruce and balsam seedlings. Mich. Agr. Exp. Sta. Quarterly Bul. 12(3): 79-81.

(21) Roe, E. I.
1946 Extended periods of seedfall of white spruce and balsam fir. U. S. Forest Service, Lake States Forest Experiment Station, Tech. Note No. 261, 1 p. (proc.).

(22) Roe, E. I.
1948 Balsam fir seed, its characteristics and germination. U. S. Forest Service, Lake States Forest Experiment Station, Station Paper No. 11, 13 pp. (proc.).

(23) Roe, E. I.
1948 Early seed production by balsam fir and white spruce. Jour. Forestry 46(7): 529.

(24) Roe, E. I.
1948 Unpublished report of March 26, 1948 on studies of intermediate-aged stands of white spruce. In files of Lake States Forest Experiment Station, 17 pp. (typed).

(25) Spaulding, P. and Hansbrough, J. R.
1944 Decay in balsam fir in New England and New York. U. S. Dept. of Agr. Tech. Bul. 872, 30 pp.

(26) Thomson, C. C.
1949 Reduced yield in a dense balsam fir stand. Canada Dept. of Mines and Resources, Dominion Forest Service, Silvic. Leafl. 32, 2 pp. (proc.).

(27) Westveld, M.
1946 Forest management as a means for controlling the spruce budworm. Jour. Forestry 44(11): 949-953.

(28) Zon, R.
1914 Balsam fir. U. S. Dept. of Agr. Bul. 55, 68 pp., illus.

FIFTY-FIVE ADDITIONAL REFERENCES ON BALSAM FIR

Anderson, A. P.
1902 Canker of Abies balsamea in Minnesota. Bul. Torry Bot. Club 29(1): 23-34, illus.

Balch, R. E.
1932 "Gout disease" of balsam fir. Forestry Chron. 8(1): 46.

_____
1934 The balsam woolly aphid, Adelges piceae (Ratz.), in Canada. Sci. Agr. 14(7): 374-383, illus.

Baldwin, H. I.
1933 The density of spruce and fir reproduction related to the direction of exposure. Ecol. 14(2): pp. 152-156.

Bannan, M. W.
1940 The root systems of northern Ontario conifers growing in sand. Amer. Jour. Bot. 27(2): 104-114, illus.

Bell, H. P.
1924 The fern rust of balsam. Bot. Gaz. 77: 1-31.

Bowman, A. B.
1944 Growth and occurrence of spruce and fir on pulpwood lands in northern Michigan. Mich. Agr. Exp. Sta. Tech. Bul. 188, 82 pp., illus.

Boyce, J. S.
1928 A conspectus of needle rusts on balsam fir in north America. Phytopath. 18. 705-708.

Brown, A. W. A. and MacKay, M. R.
1943 The jack pine budworm and the spruce budworm, Cacoecia fumiferana Clem. (Tortricidae). Canad. Ent. 75: 207-211.

Cash, E. K.
1941 An abnormality of Abies balsamea due to Sclerotinia Kerneri or a related fungus. In The Plant Disease Report. 25(22): 539-555. U. S. Dept. Agr. Bur. Plant Industry.

Chandler, R. F.
1944 Amount and mineral nutrient content of freshly fallen needle litter of some northeastern conifers. Proc. Soil Sci. Soc. Amer. 1943. 8: 409-411.

Christensen, C. M.
1937 Cephalosporium canker of balsam fir. Phytopath. 27(7): 788-791, illus.

Christensen, C. M.
1940 Observations on Polyporus circinatus. Phytopath. 30(11): 957-963, illus.

Clark, J. F.
1903 On the form of the bole of balsam fir. Forestry Quart. 1: 56-61.

Cooper, W. S.
1911 Reproduction by layering among conifers. Bot. Gaz. 52: 369-379.

Faull, J. H.
1929 A fungus disease of conifers related to snow cover. Jour. Arnold Arboretum 10: 3-8.

_____ and Mounce, I.
1924 Stereum sanguinolentum as the cause of "sapin rouge" or red heart rot of balsam. (Abstract) Phytopath. 14: 349-350.

Graham, S. A.
1923 The dying balsam fir and spruce in Minnesota. Minn. Agr. Exp. Sta. Special Ext. Bul. 68, 12 pp., illus.

Hale, J. D. and Prince, J. B.
1940 Density and rate of growth in the spruces and balsam fir of eastern Canada. Canada Dept. Mines and Resources, Lands, Parks, and Forests Branch Bul. 94, 43 pp., illus.

Heimburger, C. C.
1945 Comment on the budworm outbreak in Ontario and Quebec. Forestry Chron. 21: 114-126.

Hubert, E. E.
1929 A butt-rot of balsam fir caused by Polyporus balsameus Pk. Phytopath. 19(8): 725-732, illus.

Johnsen, B. and Reese, C. H.
1930 Spruce and balsam: Evaluation as pulpwood discussed. Paper Mill and Wood Pulp News, 8(37): 4-5, 8.

Kraemer, J. H.
1937 Suggestions for silvicultural measures in old field spruce-fir stands in the northeast. Jour. Forestry 35: 948-953.

MacAloney, H. J.
1935 The balsam woolly aphid in the northeast. Jour. Forestry 33(5): 481-484, illus.

Marriott, F. G.
1947 Canada balsam, its preparation and uses. Mimeo. Canada Forest Products Lab. No. 123, 5 pp. (proc.). (Revised by C. Greaves.)

McCallum, A. W.
1928 Studies in forest pathology 1. Decay in balsam fir. Canada Exp. Farms Div. Bot. Bul. 104 (n.s.), 25 pp., illus.

McCarthy, E. F.
1918 Accelerated growth of balsam fir in the Adirondacks. Jour. Forestry 16(3): 304-307.

McClintock, T. F. and Westveld, M.
1946 Some financial aspects of removal of overmature balsam fir as a budworm control measure. U. S. Forest Service, Northeastern Forest Exp. Sta. Forest Management Paper No. 1, 8 pp. (proc.).

McDougall, W. B.
1922 Mycorrhizas on coniferous trees. Jour. Forestry 20(3): 255-260.

McKenzie, A. R.
1950 Reproduction of pulpwood stands. Pulp and Paper Mag. Canada 51(3): 245-258.

Meyer, W. H.
1929 Yield of second growth spruce and fir in the northeast. U. S. Dept. Agr. Tech. Bul. 142, 52 pp., illus.

Moore, B.
1917 Some factors influencing the reproduction of red spruce, balsam fir, and white pine. Jour. Forestry 15(7): 827-853, illus.

———
1922 Humus content and root systems in certain northeastern forests in relation to reproduction and competition. Jour. Forestry 20(3): 233-254.

Morris, R. F.
1948 (Balsam fir) foliage analysis. Can. Dept. Agr. Bi-monthly Prog. Report Forest Insect Invest. 4(1): 1.

Mulloy, G. A.
1930 Silvicultural problems of our balsam fir-spruce type forests. Can. Woodlands Rev. 1(12): 9-10, 30-32.

———
1941 Cleaning of scattered young balsam fir and spruce in cut-over hardwood stands. Canadian Dept. Mines and Resources, Dom. Forest Service, Silvic. Res. Note 67, 19 pp. (proc.).

Peirson, H. B. and Gillespie, A. H.
1934 Some observations on the balsam woolly aphid in Maine. Jour. Econ. Ent. 27(2): 340-341.

Risi, J. and Brûle, M.
1946 Utilization of conifer branches. Perfum. essent. Oil Rec. 37(3): 78-79.

Robbins, P. W.
1928 Growth of conifers measured in Upper Peninsula. Mich. Agr. Exp. Sta. Quart. Bul. 10(3): 113-115.

Robertson, W. M.
1926 Growth of spruce and balsam fir in New Brunswick. Canada Dept. Interior, Forest Serv., 8 pp. (proc.).

_____
1942 Effect of mature yellow birch upon spruce and fir understory. Canada Dept. Mines and Resources, Dominion Forest Service Silvi. Leafl. 13, 2 pp. (proc.).

_____
1945 The forests of Newfoundland. Forestry Chron. 21: 11-21.

_____
1948 The fallacy of cutting trees before they are mature. Forestry Chron. 24(3): 182-190.

Schierbeck, O.
1922 Treatise on the spruce budworm, bark beetle and borer. The causes of the dying of the balsam in Quebec and suggestions for preventive measures. Montreal, F. J. D. Barnjum, 38 pp.

Silversides, C. R.
1945 Some observations on spruce and balsam regeneration: Black Sturgeon Concession, The Great Lakes Paper Company, Ltd. Canad. Pulp and Paper Assoc. Woodl. Sec. Index 816 (F-2), 5 pp.

Spaulding, P., Westveld, M., and Hansbrough, J. R.
1942 Balsam fir - use it, don't lose it. Pulp and Paper Mag. Canada, 43(3): 388-389.

Timber of Canada
1948 Balsam shingle research planned by Saskatchewan, 8(5): 42.

Troop, B. S.
1947 Growing balsam fir Christmas trees. Fox Forest Notes 34, 1 p. (proc.).

Waterman, A. M.
1945 The blight of species of Abies caused by a new species of Rehmiellopsis. Jour. Agr. Res. 70(10): 315-317, illus.

Weiss, F.
1940 Foreward to the revised check list of diseases of economic plants of the United States. In the Plant Disease Reporter 24(7): 140-148. U. S. Dept. Agr. Bur. Plant Industry.

Westveld, M.
1931 Reproduction on pulpwood lands in the northeast. U. S. Dept. Agr. Tech. Bul. 223, 52 pp., illus.

_____
1932 Releasing merchantable-sized spruce and fir through girdling. Jour. Forestry 30(1): 94-95.

_____
1945 Silvicultural problems of eastern Canada's pulpwood forests as viewed by an American forester. Pulp and Paper Mag. Canada (March 1945) pp. 332-334, 337.

_____ and Snow, A. G., Jr.
1940 Reproduction conditions on cut-over old-field spruce stands in New England. U. S. Forest Service, Northeastern Forest Exp. Sta. Tech. Note No. 32, 2 pp. (proc.).

Westveld, R. H.
1933 Making spruce-fir land profitable. Removal of competing hardwoods often necessary to insure growth of pulpwood. Mich. Agr. Exp. Sta. Quart. Bul. 15(4): 261-264.